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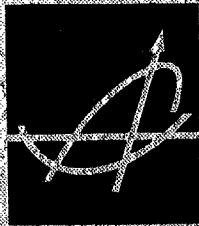
VOLUME IV

TECHNOLOGY DEVELOPMENT PLAN

SYSTEM FOR UPPER
ATMOSPHERIC SOUNDING (SUAS)

MARCH 1969

PREPARED UNDER CONTRACT NO. NAS1-7911 BY



BOOZ ALLEN APPLIED RESEARCH Inc.

FOR

NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER

VOLUME IV
TECHNOLOGY DEVELOPMENT PLAN

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Prepared under Contract No. NAS1-7911 by

Booz, Allen Applied Research Inc.
4733 Bethesda Avenue
Bethesda, Maryland 20014

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FOREWORD

This study was conducted for the Langley Research Center of the National Aeronautics and Space Administration by Booz, Allen Applied Research Inc., Bethesda, Maryland under Contract NAS1-7911. Mr. T.P. Wright, Jr., of the Flight Vehicles and Systems Division was the LRC Technical Representative of the Contracting Officer. The study was initiated on February 1, 1968 and completed on January 31, 1969.

The study was under the cognizance of Mr. C.F. Riley, Jr., Vice President, of Booz, Allen Applied Research Inc. Mr. W.E. Flowers, Research Director, was the Program Manager. Principal BAARINC staff contributors were Messrs. William E. Brockman, J. Frank Coneybear, Harry L. Crumpacker II, John L. Hain, and David W. Weiss. During the course of the study, Mr. Frederick F. Fischbach of the High Altitude Research Laboratory, University of Michigan, Mr. G. Harry Stine, a private consultant, and Dr. N. Engler, University of Dayton Research Institute, were engaged as consultants.

Reports produced as a result of this study are:

- Volume I - Summary Report
- Volume II - Technical Report
- Volume III - Conceptual Design
- Volume IV - Technology Development Plan
- Volume V - Program Development Plan.

Volume I is an overview of the project listing results and conclusions.

Volume II is the complete report on the project containing all of the technical analysis.

Volume III is the conceptual design which details the recommended sounding system.

Volume IV is the Technology Development Plan which is an orderly description of the remaining technical problems that need to be resolved prior to system procurement.

Volume V is the Program Development Plan which is an overall plan for the implementation of the system for Upper Atmospheric Sounding.

TECHNOLOGY DEVELOPMENT PLAN

1. INTRODUCTION

An objective of the Conceptual Design Study is to define the technological problems which need to be solved in order to develop the recommended system from the present level of technology. This volume contains a description of these problems and time-phase plan for their solution.

It should be noted that the recommended system does not require any technological breakthroughs in order to be developed. With the exception of the need to refine and extend the range of sphere drag coefficients, there is no requirement for basic research. All of the tasks presented in this document are of a development nature.

The recommended sounding system is composed of four inter-related elements: the payload, which includes sensors and deployment mechanisms; ground-based launch equipment; launch vehicle which contains a rocket motor and a payload container; acquisition and tracking system, and elements grouped under the general

heading of ground systems, which includes the site itself, personnel, communications and data handling equipment and the overall organization covering logistics, management, etc.

The sounding system is designed to produce a near vertical temperature/density, wind vector trace from 30 to 100 km over the launch site. In essence, an individual launch site will function as a station in a network of such stations to provide a synoptic model of the upper atmosphere. Within a site, the functional elements of the site (payload, launch vehicle, data acquisition system, etc.) form a highly interactive system.

The sphere and chaff have been designed to be as sensitive to the atmosphere and its motion as possible. The launch vehicle has been tailored to insert the sphere and chaff into an optimum trajectory from the standpoint of the measurements to be obtained. The data acquisition/tracking system is designed to follow, very closely, the motions of the passive sensors as they pass through the region of interest.

The systems design process involved the trade-off of functions between components in order to reduce development risks and to hold

overall systems operational costs to a minimum. For example, from the standpoint of the payload ejection mechanism, it is technically easier to eject the sensors near apogee and track their descent. However, from the standpoint of data acquisition/tracking accuracy,* it is desirable to eject the payload on the ascent leg of the trajectory and track the sensors as they ascend.

The designing of the system involved a series of iterations of sets of component performance specifications until a final system was reached which met the measurement requirements with a tolerable technological risk and reasonable development cost.

The development requirements resulting from this process are specified in Volume III (Conceptual Design), the remaining technical problems are summarized in this volume. A time-phased plan is included which provides a method for orderly solution to these problems for timely system implementation.

*

A full explanation of this phenomenon is contained in Volumes III and V.

2. PROGRAM PLAN

Figure 1 is a time-phased plan showing each of the development tasks and their interrelationships. The development of a suitable data acquisition/tracking system is a key task. This development effort has been studied in detail and is diagrammed in Figure 2. This task culminates in the development of the procurement specification.

3. TASK DESCRIPTION

3.1 DATA ACQUISITION AND TRACKING SYSTEM SPECIFICATION DEVELOPMENT

The tasks following represent a cohesive study effort to define the tracking system to the level of detail required for a procurement specification. This specification will be backed by precise and definitive functional system requirements which will allow NASA to evaluate manufacturers' proposals with solid background information.

3.1.1 Task 1—Complete Site Operation Plan

Develop a detailed functional plan of the complete launch event. This plan will show all steps associated with the launch event,

CUMULATIVE MONTHS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
DATA ACQUISITION & TRACKING SYSTEM																														
COMPLETE SITE OPERATION PLAN																														
REVIEW PHASED-ARRAY DEVELOPMENT																														
DEFINE RAW DATA STRUCTURE																														
DEFINE MAINTENANCE & CALIBRATION FUNCTIONS																														
DEFINE FUNCTIONAL TRACKER COMMAND STRUCTURE																														
DEFINE TRACKER/COMPUTER INTERFACE																														
DEFINE DATA REDUCTION REQMTS.																														
DEFINE SYSTEM SOFTWARE REQMTS.																														
DEFINE SYSTEM HARDWARE REQMTS.																														
DEFINE HUMAN ENGR. REQMTS.																														
DEVELOP RELIABILITY/MAINTAINABILITY PROGRAMS																														
DEVELOP SYSTEM SPECS																														
DEVELOP ACCEPTANCE TESTS																														
DEVELOP RADAR SYSTEM																														
LAUNCH VEHICLE																														
DESIGN OPTIMIZATION (MOTORS)																														
MOTOR DEVELOPMENT																														
FALLING MASS HAZARD																														
PAYOUT																														
PAYOUT LOAD EJECTION MECH.																														
DESIGN																														
FABRICATE																														
FLIGHT TEST																														
DART DEVELOPMENT*																														
DESIGN																														
FABRICATE																														
GROUND TEST																														
FLIGHT TEST																														
SPHERE DRAG COEF.																														
SPHERE FABRICATION																														
GENERAL																														
SITE DESIGN SPEC																														
SYNOPTIC SYSTEM DESIGN																														
NETWORK ANALYSIS																														
DATA ANALYSIS & HANDLING																														
NETWORK COMMUNICATIONS																														
SYSTEM MANAGEMENT																														
RELIABILITY/MAINTAINABILITY																														

* PENDING DART SELECTION
 FIGURE 1. Development Master Plan

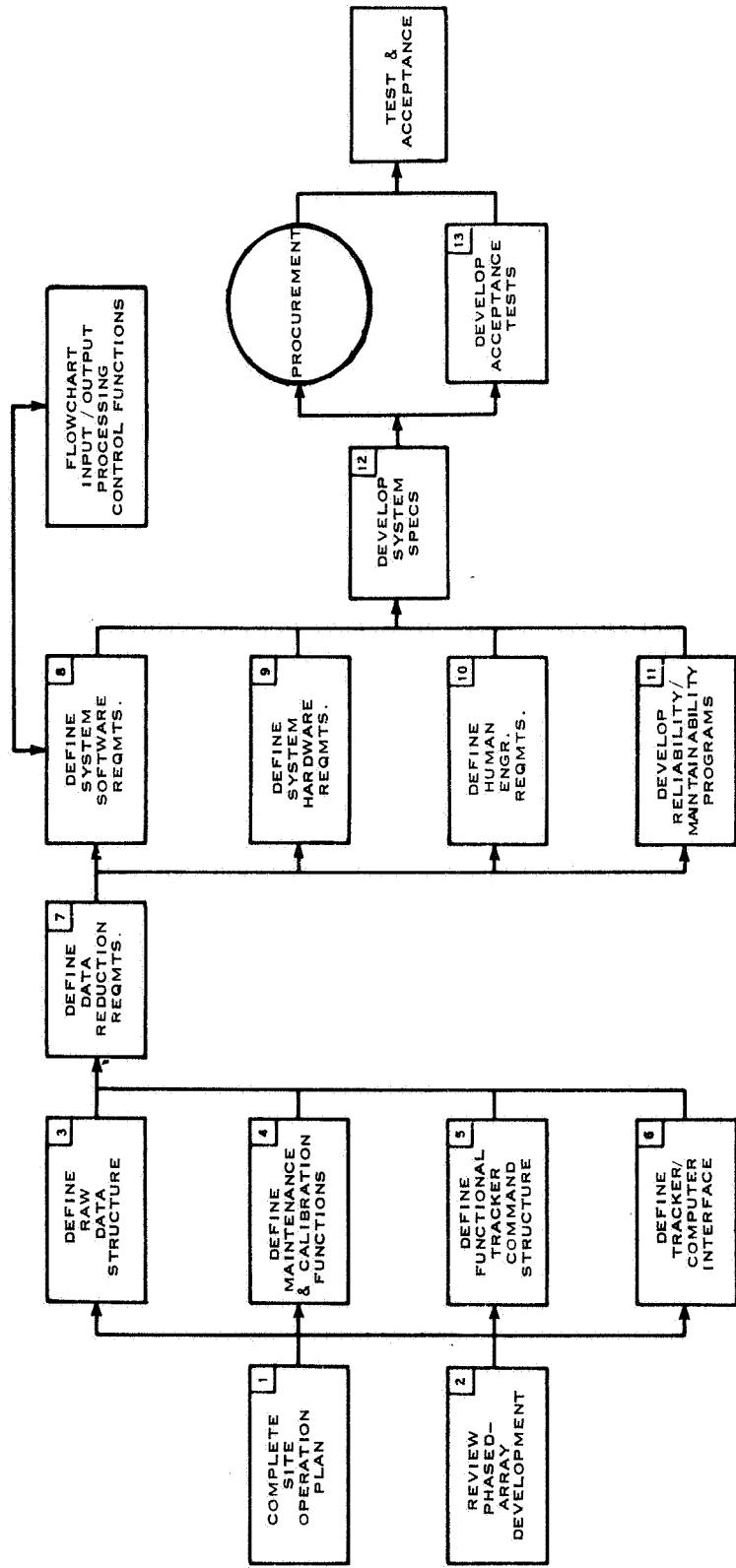


FIGURE 2. Tracking and Data Acquisition System Development Plan

properly time-phased, including preparation, the launch itself, the measurements cycle, all data collection and reduction, shutdown and refurbishment.

3.1.2 Task 2—Review Phased-Array Development

A detailed study of applicable phased-array development projects (Air Force and Navy), to determine the optimum final configuration; one that will take advantage of developed circuitry, software, manufacturing techniques, etc. This study will define the current distribution of operational tasks between hardware, software and operators. It will identify any restrictions as to the physical location or arrangement of equipment.

3.1.3 Task 3—Define Raw Data Structure

A detailed examination of the measurement trajectory to define the form and structure of the time/position trace developed by the tracker.

3.1.4 Task 4—Define Maintenance and Calibration Function

Define the overall maintenance and calibration requirement for the Data Acquisition/Tracking System, including installation as well as normal operational requirements.

**3.1.5 Task 5—Define the Functional Tracker
Command Structure**

Develop the tracker command requirements to perform acquisition track and data collection under computer control.

3.1.6 Task 6—Define the Tracker/Computer Interface

Develop a functional specification of the Tracker/Computer Interface.

3.1.7 Task 7—Define Data Reduction Requirements

Develop the optimum method of wind/temperature/density inference from the time/position trace developed during tracking.

3.1.8 Task 8—Define System Software Requirements

Develop the computer inputs, outputs, control functions and processing requirements. These requirements have been tentatively grouped into seven categories:

- (a) Executive routines
- (b) General-purpose routines
- (c) Meteorological routines

- (d) Supervisory control
- (e) Calibration routines
- (f) Maintenance routines
- (g) System monitor routines.

This effort should result in functional flowcharts of the software system.

3.1.9 Task 9—Define System Hardware Requirements

Develop a functional description of the hardware required by the Data Acquisition/Tracking System.

3.1.10 Task 10—Define Human Engineering Requirements

Develop the human factors to be employed in the design to make the system as self-sufficient as practical and to function smoothly with the level of operator personnel anticipated on site.

3.1.11 Task 11—Develop Reliability Program

This step should be accomplished in concert with the overall reliability/maintainability program for the entire site. A single project should be initiated to establish the reliability/maintainability

philosophy for the sounding system in order to conduct trade-offs of cost/reliability/effectiveness across the entire system, and execute a uniform reliability/maintainability program throughout the R&D phase.

3.1.12 Task 12—Develop System Specification

Develop a procurement specification which will ensure that:

- (1) every technical requirement of the system will be met by the developed product, (2) no qualified manufacturer will be excluded from bidding due to unnecessary hardware restrictions, and
- (3) manufacturers will be encouraged to exercise their ingenuity in design and manufacturing to produce the best product for the lowest price.

3.1.13 Task 13—Develop Acceptance Test Procedures

Develop a set of acceptance test requirements and procedures to be used at time of delivery. This task will be accomplished in conjunction with the reliability program and proof-tested during system integration.

3.2 LAUNCH VEHICLE DEVELOPMENT

3.2.1 Design Optimization

A detailed design study should produce a motor design for an optimum booster-dart combination and an optimum long-burning motor. These designs must be optimized on the basis of present technology. Specific impulse, burning time, and propellant mixtures must not be projected beyond those having passed static tests. Competitive bids will be sought afterward.

3.2.2 Falling Mass Hazard (FMH) (Continuing Effort)

LRC currently has a development project underway to solve the falling mass hazard associated with small meteorological rockets. This effort should continue and dovetail with motor development.

If operational launch site activation begins through the use of existing ranges such as WSMR, AMR, PMR and Wallops Station, then the system can begin limited operation years before the falling mass hazard problem is eliminated. All facets of the system from hardware through logistics and data reduction can be tested and brought to operational status. There are several specific FMH areas that need to be studied with regard to this system.

- (a) The impact that current rocket and rocket-boosted dart technology will have on launch site selection and grid spacing.
- (b) A trade-off analysis between the rocket and rocket-boosted dart techniques.

3.3 MOTOR DEVELOPMENT

Contract for motor development by qualified manufacturer based on design optimization study. Estimated cost is \$300, 000.

3.4 PAYLOAD DEVELOPMENTS

3.4.1 Payload Ejection (\$100, 000)

Develop a mechanism which will eject the sphere at the proper time followed by a chaff ejection many seconds later. Sphere ejection must be preset and be reliable within \pm 1 second. The sphere must be ejected at a specified velocity.

3.4.2 Dart Development (\$300, 000, including payload ejection mechanism)

If the dart concept proves to be the optimum system after design optimization and competition, then a prototype of the dart design

should be built and ground tested. After satisfactorily passing ground tests, the dart payload should be flight tested on a suitable current rocket.

3.4.3 Sphere Drag Coefficient

A sphere drag coefficient research project should be conducted. This project would be conducted in two phases. The first phase would be an investigation of the drag coefficient requirements, i.e., the deficiencies in the present data and recommendation for the experiments required to correct these deficiencies. The second phase would be experimentation, analysis and verification of results. The first phase would require approximately \$50,000 and the second phase would require \$200,000, assuming the experiments could be conducted in government-owned facilities. This program is urgent and has current applications to other programs. The way the program is managed is as vital as the research results because of the scientific implications.

3.4.4 Sphere Fabrication (\$100,000)

A design study to develop optimum sphere fabrication techniques consistent with anticipated production volumes. This study

should also optimize inflation and packaging techniques. This may be accomplished during procurement competition, however, this method will raise the technical risk associated with the final product.

3.5 GENERAL DEVELOPMENT

3.5.1 Site Design Specification

A design requirements study should be conducted to develop a design criteria document which specifies the launch site to a level of detail sufficient for an architect to design specific plans once sites are selected.

3.5.2 Synoptic System Design

The present effort has concentrated on the technical requirements for the system. A study should not be initiated which defines the following items.

3.5.2.1 The Network

The network in terms of minimum grid spacing, optimum grid spacing, domestic system and worldwide system requirements. This study should also document all possible, available, government sites,

and facilities including communication, distribution and data processing systems. This study should show the trade-off in using these sites and facilities as opposed to unrestricted site selection and facility design.

3.5.2.2 Data Analysis and Handling

A study which details the optimum method of density, temperature and wind data inference given the tracking time/location trace, and where this data reduction can best be accomplished (field site or central). This task should be accomplished in conjunction with task 7 of the tracker/data acquisition study, and the network analysis above.

3.5.2.3 Network Communications

A study to determine the communications required by the network based on data volumes, etc.

3.5.2.4 System Management

Develop an operational plan for the system including all aspects from the field sites to overall network control.

3.5.2.5 RELIABILITY/MAINTAINABILITY

3.5.2.6 Establish Philosophy and Programs

Develop a reliability plan. Establish all reliability controls and documentation.

3.5.2.7 Conduct Reliability Trade-Offs

Conduct systems and subsystems trade-off analysis to determine reliability requirements for each component (launch vehicle, payload, etc.) for use in procurement specification. This may result in the development of a reliability incentive plan for procurement.

3.5.2.8 Monitor Reliability Program

Oversee the reliability program from initial planning through production. The six man-months is a total requirement and will be stretched over the entire development phase.

4. CONCLUSIONS

4.1 TRACKING AND DATA ACQUISITION SPECIFICATION

The steps in the Tracking and Data Acquisition System Development Plan, shown in Figure 1, represent a single cohesive interactive study effort. This study should be accomplished by a single contractor.

4.2 LAUNCH VEHICLE

4.2.1 Design Optimization

This study is a direct extension of work already accomplished in the section of the Conceptual Design study devoted to launch vehicles.

4.2.2 Motor Development

This is a hardware development task which should follow the design optimization study. Ideally, it will draw on the Conceptual Design and the design optimization study and should be accomplished as a result of a competition between reliable manufacturers.

4.2.3 Falling Mass Hazard

This should be an extension of the on-going MICOM/LRC* effort. However, it should also draw on the Conceptual Design requirements as well as the design optimization study and motor development contract. This project has a period of years before a definite solution is required depending on the site acquisition plan.

4.3 PAYOUT

4.3.1 Payload Ejection Mechanism

This is a hardware development project which should be accomplished through an appropriate manufacturer. However, it must be coordinated with the motor development project, the motor optimization study and the sphere fabrication techniques study.

4.3.2 Sphere Drag Coefficient Study

Drag coefficient tables have been produced at three primary sources:

* MICOM - Army Missile Command
LRC - Langley Research Center.

University of Michigan, 1962
Aroesty and Heinrich

University of Dayton, 1965
Heinrich

Sandia Corporation, 1967.

If all three are reproduced on the same graph, there is general disagreement in some cases by as much as 20%. For example, at a Mach number of 0.75, Reynolds number of 1,000, the Michigan drag coefficient is 0.5 and increasing with increasing Reynolds number; the Dayton value is 0.55 and constant with increasing Reynolds number and the Sandia value is 0.58 and decreasing with increasing Reynolds number.

Basic differences exist in the design of the experiments that produced these various data. The Sandia Corporation moved the sphere in a stationary fluid while Heinrich holds the sphere stationary and moves the fluid.

The first step in the study to refine drag coefficients should be a careful analysis of all available drag data and a projection of the anticipated trajectory to determine the exact Mach and Reynolds number ranges required. The next phase would be the development of

and conduct of a series of subsonic and supersonic experiments to produce the required drag data. It is recommended that an experimental design steering committee be formed to assist in the design of the experiments and in the review of the results. A recommended panel would include the contractor with representatives of government agencies, universities, and others in the area. The experimental package should be conducted by an appropriate Research facility under contract to LRC. This study has current applications to other pertinent upper atmospheric research and should begin promptly.

4.3.3 Sphere Fabrication

The system will use very large quantities of inflated spheres (10,000 per year). Sphere fabrication techniques currently are gaged to very small quantity production. Significant savings should be available, and a possible improvement in sphere quality (through the development of special-purpose equipment) may result from mass production. A study which is designed to develop mass production techniques should be undertaken. With high quantity production orders, however, a competition among possible manufacturers may accomplish the same result.

4.4 GENERAL

4.4.1 Site Design Specification

A design criteria document should be developed which outlines the site characteristics to the level of detail necessary for an architect to design specific plans once sites are established. A secondary purpose of this study should be to consider standard modules of construction which might be used at any site.

4.4.2 Synoptic System Design

A comprehensive study of the actual operational aspects of this system should be undertaken. This is essential to the implementation of the system, and can serve as a part of the justification document used as a vehicle for project approval.

4.4.3 Reliability and Maintainability

This system will require closely controlled and highly integrated design from the standpoint of maintainability in the field and reliability. The elements of the system are complex and highly interactive. In order to make the system simple to operate, a serious effort is required from system concept to field construction in the area of reliability and maintainability.